Effect of timing and intensity of drought on the seed yield of white clover (*Trifolium repens* L.).

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Abstract

The response of white clover (Trifolium repens L.) seed yield to timing and intensity of drought was determined in a mobile rainshelter, which excluded rainfall during crop growth. Eight irrigation treatments were applied from late winter until the crop was desiccated before harvest in February. These treatments subjected the crop either to drought at different stages during plant growth or to irrigation at different frequencies. Total crop dry weight generally increased linearly with cumulative water use. In contrast, the lowest seed yields came from treatments fully irrigated either throughout or from closing. Highest seed yields came from crops irrigated at either three or four weekly intervals throughout, or irrigated during flowering. Seed yield was closely related to seed head number, with no effect of floret number/head, seed numbers/head or seed size.

Key Words

Soil moisture, evapotranspiration, potential deficit, harvest index.

Introduction

White clover seed worth about $25 million is produced annually in New Zealand, and about $18 million worth is exported (1). According to White (2), the timely use of irrigation on white clover grown for seed production is one of the most effective ways to increase yields, but results may be disastrous if water is applied at the wrong time. He writes that clover irrigation management is as much an art as a science, and that some water stress is essential to promote reproductive growth and minimize leaf production. Farm consultants have recently developed an irrigation recommendation based on experience, but have been unable to test it because of untimely rainfall. Therefore, to clarify the effect of water stress on white clover seed yield, we carried out an experiment in a rainshelter, where rainfall was excluded from experimental plots otherwise exposed to normal weather (3).

Materials and Methods

The rainshelter at Lincoln, Canterbury, New Zealand, is a mobile 55 m x 12 m greenhouse, which automatically covers the experimental crop during rainfall, but is otherwise positioned some 50 m away (3). The soil is a deep (>1.6 m) Templeton sandy loam (*Udic Ustochrept*, USDA Soil Taxonomy) (4) with an available water holding capacity of c. 190 mm/m of depth.

'Alice' white clover (0.64 mg seed weight, 92% laboratory germination) was sown on 3 April 2001 in 30 cm rows with a single row cone seeder at a seeding rate of 3 kg/ha. Eight treatments were applied:

- FULL: Full irrigation weekly from late winter (3 September) to harvest, adding the weekly actual soil moisture deficit.
- NIL: No irrigation from late winter to harvest.
- LD: Late drought, i.e. full irrigation to early November (closing), then no irrigation to harvest.
- ED: Early drought, i.e. no irrigation to early November, then full irrigation to harvest.
- 20MM: Full irrigation to early October, then add 20 mm whenever soil moisture drops to 20% available soil moisture (0-60cm), except from start to full flower, when 20 mm/week is applied (current consultants recommendation).
- 2WK: Irrigate every 2 weeks from late winter with same amount of water applied to FULL that week.

- 3WK: Irrigate every 3 weeks from late winter with same amount of water applied to FULL that week.
- 4WK: Irrigate every 4 weeks from late winter with same amount of water applied to FULL that week.

The experiment was a randomised complete block design with three replicates. Plot size was 5 by 3 m. Irrigation treatments started on 3 September, when the soil moisture deficit to 1.5 m was 16 mm below the maximum recorded. Each plot had its own trickle irrigation supply, with emitters spaced 300 x 450 mm apart. All treatments scheduled for irrigation received the same amount of water, equal to the actual water use of FULL during the previous week. This was measured to 1.6 m by time domain reflectometry (0-20 cm) and a neutron probe (20-160 cm at 20 cm intervals). The potential soil moisture deficit (PSMD) for each treatment was calculated as the accumulative difference between daily Penman potential evapotranspiration (PET), calculated from meteorological data collected 500 m away, and the amount of irrigation applied to that treatment. The maximum PSMD attained during the growth of crop was used as a measure of drought severity (5).

The crop was fertilized and sprayed to avoid any limitation to yield other than drought. Crop yield components were determined on two 0.5m^2 quadrats taken from each plot on 23 January. At the same time the height of 10 seed heads and top leaves were measured in each plot. The crops were desiccated on 8 February; NIL and LD were sprayed with Diquat and the other treatments were sprayed with MCPA, followed by Diquat on 21 and 26 February. NIL and LD were harvested on 20 February and the others on 8 March. For seed yield, two 45 cm strips were taken across 2.75 m of each plot with a rotary lawn mower. The mown material was threshed in a plot header. The seed was then cleaned on a belt seed cleaner, and graded in a vertical draught seed separator.

Results

Flowering started in early November, and peak flowering occurred in late December. Irrigation and water data are given in Table 1 and yield data in Table 2. The weekly irrigations ranged from 10 to 27 mm. PET from September to February was 516 mm, 87% of the long term mean.

Table 1. Irrigation number, water applied and used, and maximum potential soil moisture deficit (MPSMD)

Treatment	Irrigation no	Water applied (mm)	MPSMD (mm)
FULL	18	401	140
NIL	0	9	532
LD	7	133	408
ED	11	277	264
20MM	9	176	365
2WK	9	196	344
3WK	6	139	404

4WK	4	102	466

Water use was 2.4 times higher for FULL compared to NIL (Table 2). However, despite large differences in water applied (Table 1), the water use of a number of treatments was similar (Table 2).

Highest seed yields were from LD, 20MM, 3WK and 4WK (Table 2). Total seed yields for NIL (577 kg/ha) were significantly higher than for FULL and ED (average 387 kg/ha), but significantly lower than for 20MM and 3WK, which averaged 827 kg/ha. The percentage of second grade seed was significantly higher in FULL and LD (average 25%) than in all other treatments (6 – 15%).

Seed yield showed a non-linear relationship with maximum potential soil moisture deficit (MPSMD) (Figure 1a), with an optimum MPSMD around 400 –500 mm. There was a poor relationship between seed yield and WU (Figure 1b), with double the seed yield obtained from 20MM as from ED for the same water use (WU) (Table 2). LD, 2WK and 4WK had similar seed yields over a range of WU.

Seed yield was closely related to seed head number (r=0.96). NIL and LD had significantly higher head numbers than FULL or ED, but significantly less than 3WK or 4WK (Table 2). Individual seed head weight (mean 0.25 g), seed head floret number (62.1), seed weight per floret (0.14 g) and first grade seed weight (0.70 mg) were not significantly (P<0.05) affected by the irrigation treatments. However, significantly more flowers and buds were continuing to be produced from the more watered treatments at harvest (Table 2).

Total crop dry weight from the quadrats ranged from 6 to 15 t/ha of dry matter (11 to 62 t fresh weight/ha). Highest total above ground dry weight (vegetative plus reproductive) came from the most irrigated treatments (Table 2), with linear relationships between total crop yield and both MPSMD (r = 0.83 above 300 mm MPSMD) and WU (r = 0.82).

Table 2. Seed yield, % seconds, seed head and flower plus bud number, total dry weight (DWT) and harvest index.

Treatment	Actual water use (mm)	Seed yield (kg/ha)	% seconds	Seed head no/m2	Flower and bud no/m2	Total DWT (t/ha)	Harvest Index (%)
FULL	401	365	27.3	317	80	15.2	1.7
NIL	169	577	14.5	638	12	6.1	9.0
LD	295	689	10.2	634	36	10.5	7.1
ED	297	409	23.3	451	99	13.9	2.6
20MM	299	818	6.3	724	67	10.8	8.2
2WK	317	674	10.0	752	91	14.5	5.8
3WK	259	836	9.9	903	97	12.8	8.1

4WK	233	743	9.0	789	56	10.4	8.7
LSD (5%) (df 14)	38.3 ***[1]	158.0 ***	6.98 ***	132.4 ***	25.7 ***	2.16 ***	1.70 ***
CV.	7.3	14.0	28.4	11.6	21.7	10.5	15.2

[1] *** = Significant at P<0.001,

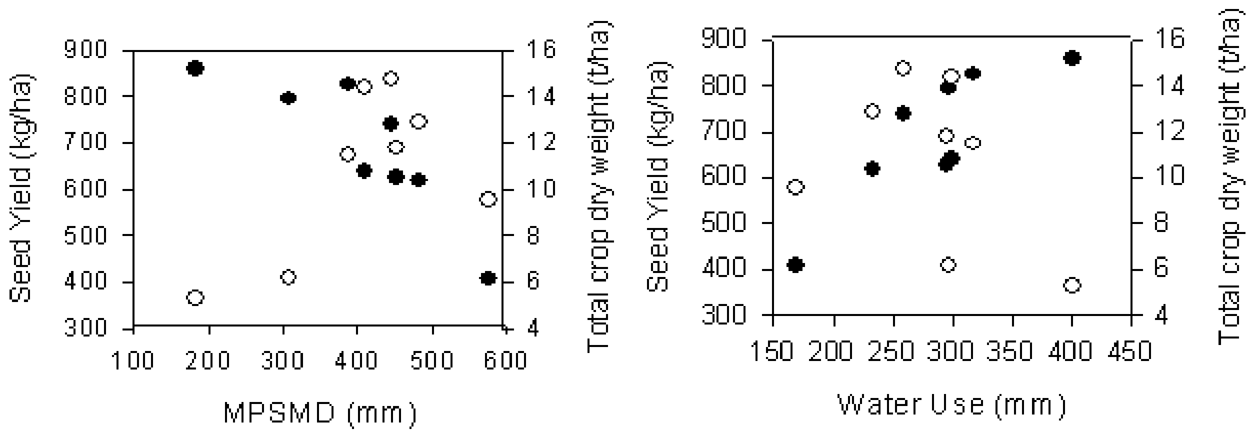

Figure 1. Effect of (a) maximum potential soil moisture deficit (MPSMD) and (b) water use on seed yield (○) and total dry matter yield of white clover (●).

Harvest index, calculated from the quadrat seed yields and total dried biomass yields, and expressed as a percentage, was under 10% for all treatments, and as low as 2% in FULL and ED. Harvest index increased linearly with MPSMD (r = 0.92).

Discussion

The results from this trial confirm previous findings (6) that moisture stress during reproductive development will reduce seed yield by limiting flower head production, and that over-irrigating also reduces seed yield because vegetative growth is encouraged at the expense of reproductive growth.

Unlike annual crops tested in the rainshelter, such as cereals (7) and peas (8), white clover seed yield did not have a linear relationship between seed yield and water use or maximum PSMD. We obtained similar unpublished results with a perennial ryegrass seed crop, indicating that, in perennial crops where harvest index is low, the balance between water stress, vegetative and reproductive growth is much more complex than in annual crops.

The stage of clover growth where water stress occurred was also important for seed yield, unlike the situation in cereals and peas (7, 8). Timing of the stress has to occur during clover reproductive development to be effective, as vegetative and reproductive growth occur together during flowering, unlike annual crops, where they usually occur in sequence.

20MM was designed to keep just enough water up to the plants during flowering to maximize flower head production and seed set, without encouraging vegetative growth. This treatment was one of the highest yielding, but needs regular soil profile moisture measurements to be implemented. 3WK and 4WK produced very similar seed yields to 20MM, indicating that, in this cooler than average season on this soil type, a water budgeting system based on a 3-4 week irrigation interval would have worked just as well, using 20% less irrigation water.

A predictive system, based on PSMD, works well for other annual crops, where there is a linear relationship between MPSMD and seed yield (7, 8). In clover this was not the case, but there is a 400-500 mm optimum range of MPSMD that could be aimed for to maximize seed yield. To schedule irrigation using this method will require a target PSMD to be reached during flowering. In this trial, PSMD in the highest yielding treatment was 250 mm in mid November and 300-400 mm at Christmas.

Conclusions

White clover was sensitive to time of water application. Both too little and too much water during the flowering period reduced yields.

On this soil type, around 100 mm of water applied during flowering would be sufficient to maximize seed yields without encouraging vegetative growth.

The results indicate that irrigation scheduling based on soil moisture, time or potential deficits can be developed for white clover seed production, with potential savings in water applications.

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